Oyster Mussel
(*Epioblasma capsaeformis*, Lea, 1831)

5-Year Review:
Summary and Evaluation

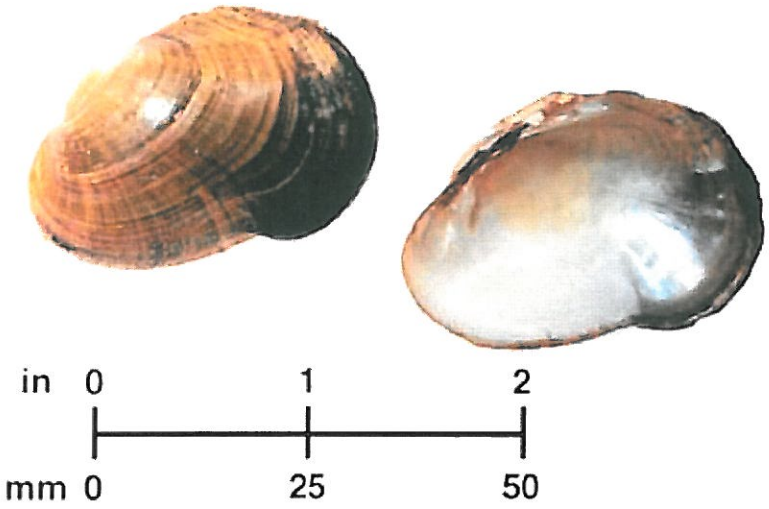

Photo by Jess Jones, U.S. Fish and Wildlife Service

U.S. Fish and Wildlife Service
Southeast Region
Tennessee Ecological Services Field Office
Cookeville, Tennessee

5-YEAR REVIEW
Oyster Mussel (*Epioblasma capsaeformis*)

I. GENERAL INFORMATION

A. Methodology used to complete this review

This review was completed by the U. S. Fish and Wildlife Service's Cookeville Field Office and reviewed by Jess Jones of the Virginia Field Office. All literature and documents used for this review are on file at the Cookeville Field Office. The primary source of information used in this analysis was the final recovery plan (Service 2004) and the best available information we have gained since our last 5-year review. Public notice of this review was given in the *Federal Register* on August 30, 2016 (81 FR 59650) and a 60-day comment period was opened. During this comment period, we obtained additional information on the status of this species from several experts and our State partners. In addition to sharing this with our State partners, this review was also sent to five mussel experts for peer review (Appendix A).

B. Reviewers

Lead Region - Southeast Region: Kelly Bibb, (404) 679-7132

Lead Field Office - Cookeville, TN: Stephanie Chance, (931) 528-6481

Cooperating Field Offices - Virginia: Jordan Richard, (276) 623-1233; Jess Jones, (540) 231-2266; Alabama: Anthony Ford (251) 441-5838; Kentucky: Leroy Koch, (502) 695-0468; North Carolina: Andrew Henderson (828) 258-3939; Georgia: Robin Goodloe (706) 613-9493

Cooperating Regional Office – Northeast Region: Mary Parkin, (617) 876-6173

C. Background

1. **Federal Register Notice citation announcing initiation of this review:**
   August 30, 2016; 81 FR 59650

2. **Species status:** Declining, monitoring data demonstrates populations have declined in all occupied rivers since the last review was conducted in 2009.

3. **Recovery achieved:** 1 = 0%-25% recovery objectives achieved

4. **Listing history**
   Original Listing
   FR notice: 62 FR 1647
   Date listed: January 10, 1997
   Entity listed: species
   Classification: endangered

5. **Associated actions**
   Designation of critical habitat for five endangered mussels (including the oyster mussel) in the Tennessee and Cumberland River basins (69 FR 53136).

   Establishment of nonessential experimental population status for 16 freshwater mussels (including the oyster mussel) and 1 freshwater snail in the free-flowing reach of the Tennessee River below the Wilson Dam, Colbert and Lauderdale Counties in Alabama (66 FR 32250).

   Establishment of nonessential experimental population status for 15 freshwater mussels, 1 freshwater snail, and 5 fishes in the lower French Broad River and in the lower Holston River, Tennessee (72 FR 52434).

6. **Review History**
   Recovery Plan: 2004

   Each year, the Service reviews and updates listed species information for inclusion in the required Recovery Report to Congress. Through 2013, we did a recovery data call that included status recommendations such as "Stable" for this mussel. We continue to show that species status recommendation above as part of our 5-year reviews. The most recent evaluation for this mussel was completed in 2018.

   Last 5-Year Review: 2009. We reviewed the best available information since our recovery plan and did not recommend a change in status for this mussel.

7. **Species' Recovery Priority Number at start of review (48 FR 43098):** 5 (degree of threat is high, potential for recovery is low, and the taxonomy is the species level)

8. **Recovery Plan**
   Name of plan: Recovery Plan for Cumberland Elktoe, Oyster Mussel, Cumberlandian Combshell, Purple Bean, and Rough Rabbitsfoot.

Date issued: May 4, 2004

II. REVIEW ANALYSIS

A. Application of the 1996 Distinct Population Segment (DPS) policy: Not applicable. The oyster mussel is an invertebrate, and therefore, not covered by the DPS policy, and the other DPS questions will not be addressed further in this review.

B. Recovery Criteria

1. **Does the species have a final, approved recovery plan containing objective, measurable criteria?** Yes.
2. **Does the recovery plan contain recovery (i.e., downlisting or delisting) criteria?** Yes.

3. **Adequacy of recovery criteria.**
   a. **Do the recovery criteria reflect the best available and most up-to-date information on the biology of the species and its habitat?** No, a new morphologically and genetically diagnosable species has been described from the oyster mussel species complex (Jones and Neves 2010). The Service believes this information is supported in the scientific community and recommends in this review that the new species, *Epioblasma ahlstedti* (Duck River Dartersnapper), be considered for listing under the Endangered Species Act of 1973, as amended (Act) (see section IV. Recommendations for Future Actions). A 5-year review is not a rulemaking document. For the Service to initiate a new listing action, we would have to do so through the rulemaking process. If the species complex is recognized by the Service, a new Recovery Plan (s) may have to be considered, incorporating threats-based criteria for both species, including the originally listed oyster mussel and the newly described Duck River Dartersnapper. Until that time of consideration, the oyster mussel remains federally protected as an endangered species.

   b. **Are all of the 5 listing factors that are relevant to the species addressed in the recovery criteria (and there is no new information to consider regarding existing or new threats)?** No, the recovery criteria do not reflect the current knowledge of the species and do not include threats-based information considered separately for the two species, oyster mussel and Duck River Dartersnapper. To reflect the best available information, we are going to present the species complex identified in Jones and Neves (2010) from this point forward in the document. We note that this 5-year review will not change the oyster mussel's original

listing under the Act. The Service must initiate the rulemaking process (which includes a proposed rule and open public comment period) to do this.

4. Recovery criteria

a) Criteria for downlisting to threatened status

Through the protection of extant stream populations (e.g., continuing to use existing regulatory mechanisms, establishing partnerships with various stakeholders, using BMPs, minimizing or eliminating threats), discovery of currently unknown stream populations, and/or reestablishment of historical stream populations, there exists at least six distinct viable stream populations of the oyster mussel in the Cumberland River system, upper Tennessee River system, and/or lower Tennessee River system. This will be accomplished by:

We would like to share before discussing the criteria below that the discovery of unknown stream populations is unlikely and the focus of recovery efforts has been to protect known extant populations and on the reestablishment of historical populations.

1) Protecting all extant populations (i.e., lower Clinch River, Nolichucky River in the upper Tennessee River system, and Duck River in the lower Tennessee River system) and ensuring that all these streams have viable population status.

While we have not met this criterion yet, we are working with our State and Federal partners and The Nature Conservancy (TNC) to protect extant populations of the oyster mussel and Duck River Dartersnapper. The species are included in State Wildlife Action Plans in Alabama, Tennessee, and Virginia.

In response to increasing concern over declines in freshwater mussels in the Clinch River in Virginia, Regions III and IV of the U.S. Environmental Protection Agency, Tennessee Department of Environment and Conservation, Virginia Department of Environmental Quality, and Virginia Department of Mines, Minerals, and Energy signed a Memorandum of Understanding (MOU) in 2007 to establish a working group for improving communications and coordinating efforts to protect and restore the Clinch and Powell rivers. These agencies and others are continuing to work together to accomplish common goals of reducing human impacts associated with coal mining and processing, agriculture, urbanization, and the development of transportation corridors. The Clinch-Powell Clean Rivers Initiative (CPCRI) continues to carry out the goals stated in the MOU, including Acid and Abandoned Mine Land reclamation, sewage plant updates, water quality monitoring, the establishment of Total

Maximum Daily Loads to limit pollutants in the watershed, and mussel population augmentation and reintroductions.

As part of their efforts, the CPCRI has prepared a "Biodiversity Conservation Science Plan for the Clinch-Powell River System, Virginia – Tennessee, USA" to outline science needs for the watersheds that will be updated on an ongoing basis. Since 2009, the CPCRI partners have been using the plan as a guide to coordinate and conduct studies to characterize mussel population status, physical habitat, and water quality in the Clinch and Powell Rivers. In 2014, these studies were published in a special series of articles in the Journal of the American Water Resources Association (Zipper et al. 2014). These studies will help landowners, land managers, and regulatory agencies to make decisions regarding the conservation of federally listed and other sensitive species.

The Virginia Department of Conservation and Recreation (DCR) and TNC are working to develop a Clinch River State Park on the Virginia side of the Clinch River. The park would be a series of riverside properties along the length of the river. Funds have been secured and lands are being acquired from willing sellers/donors.

The Service, TNC, local Soil and Water Conservation Districts, the Natural Resources Conservation Service, Farm Service Agency, Clinch-Powell Resource Conservation and Development Council, and many State agencies and local partners are working together to protect aquatic biodiversity in the Clinch-Powell watershed by providing monetary and technical assistance to facilitate the protection and recovery of riparian corridors and the reduction and prevention of non-point source pollution on private lands.

Through their Landowner Incentive Program, TNC has provided monetary and technical assistance to facilitate the protection of riparian corridors along the Duck River to prevent non-point pollution from private lands.

In 2013, TNC and a core team of collaborators developed a strategic plan for Tennessee freshwater mollusk conservation (TNC 2013). The strategy outlines priority areas for mollusk protection and restoration within the state. It identifies areas for protection based on threats from poor agricultural practices, incompatible resource extraction, current development risk, and future development risk (TNC 2013). In addition, it identifies research needs and next steps for population restoration and augmentation (TNC 2013).

2) **Reestablishing three viable stream populations in any of the following streams: (a) Cumberland River system (e.g., Rockcastle River, Buck Creek, Big South Fork, Little South Fork, Red River); (b) upper Tennessee River system**

(e.g., upper Clinch River, Powell River, upper Holston River/North Fork Holston River, lower Holston River, French Broad River); and/or (c) lower Tennessee River system (e.g., Paint Rock River, Elk River, Tennessee River at Muscle Shoals, Shoal Creek, Bear Creek, Buffalo River).

This criterion has not been met. However, the Service and many partners in Kentucky, Tennessee, and Virginia have been working to reestablish populations or to augment oyster mussel populations in the Tennessee and the Cumberland River systems. However, the geographic split between the oyster mussel and Duck River Dartersnapper likely occurs in the middle section of the Tennessee River below Wilson Dam at Muscle Shoals, AL or below Pickwick Dam, TN (Jones and Neves 2010). Thus, any efforts to reestablish populations should consider the new taxonomy (e.g., efforts in the Buffalo River, TN or Bear Creek, AL and MS should use the Duck River Dartersnapper from the Duck River).

Oyster Mussel:

Cumberland River System

Little South Fork of the Cumberland River

The Little South Fork mussel fauna is all but gone, with only 5 species found live and no evidence of reproduction (Ahlstedt et al. 2014). Ahlstedt et al. (2014) noticed numerous gas wells in the watershed, with oily sheen and odors observed at one of their study sites. Reestablishment of oyster mussel in this portion of the Cumberland River system is not an option at this time.

Upper Tennessee River system

Clinch and Powell Rivers

Between 2009 and 2015, the Virginia Department of Game and Inland Fisheries (VDGIF, Aquatic Wildlife Conservation Center (AWCC)) has released 12,441 sub-adult (1-2 year old) oyster mussels into the Clinch River and 2,239 into the Powell River. During the same period, Virginia Tech (Freshwater Mollusk Conservation Center, FMCC) has released 34,304 oyster mussel individuals (a mix of adults, sub-adults, and juveniles) into the Clinch River and 9,832 into the Powell River.

Emory, Hiwassee, and Nolichucky Rivers

Between 2009 and 2015, the Tennessee Wildlife Resources Agency (TWRA) has translocated 1,620 oyster mussels into the Emory River and 8,834 oyster mussels into the Nolichucky River (upstream of the heavy agricultural impacts) with adults and juveniles propagated from Clinch River broodstock. From 2012 to 2014, 2,769 oyster mussels were reintroduced into the Hiwassee River. The Nolichucky reintroductions appear to be successful, but the Emory and Hiwassee river reintroductions were not successful and stocking in these rivers ceased in 2016 (Phipps et al., 2017).

French Broad River Non-Essential Experimental Population (NEP)
In 2007, the Service finalized an NEP rule (72 FR 52434) for the lower French Broad and lower Holston rivers that allows for the establishment of at least two new populations of the oyster mussel. From 2010 to 2012, Moles (2014) translocated 800 adult oyster mussels from the Clinch River, Tennessee into the lower French Broad River NEP. In the first year post-stocking, less than 40 percent of mussels persisted, with further declines in the subsequent 2 years of study. After a period of 3 years, less than 10 percent of translocated oyster mussels were retained (Moles 2014). Males had higher retention rates than females, but both sexes experienced a decline in growth and less than half of the females were able to undergo gametogenesis post stocking. Those females that were gravid exhibited high fertilization success throughout the study (> 95%) (Moles 2014).

Oyster mussels move horizontally across the surface of the substrate during unfavorable flow conditions (Moles 2014). Additionally, females move to and position themselves on the substrate surface to display a mantle lure to attract fish hosts while spawning. These behaviors might expose the females to high stream velocities and make them particularly susceptible to dislodgement due to high discharges from Douglas Dam (Moles 2014). However, there was no evidence that water temperatures limited survival or reproduction of the oyster mussels that remained at stocking sites (Moles 2014).

Due to high flows from Douglas and Cherokee Dams, oyster mussel restoration efforts are not a recommended option in the lower French Broad and Holston rivers NEP at this time.

Elk River
In 2016, the TWRA added the Elk River at Winding Stair Bluff, Giles County, TN, to its annual oyster mussel stocking sites and released 104 adults, using broodstock from the Clinch River at Kyle's Ford.

Paint Rock River
Fobian et al. (2014) assessed the mussel assemblage in the Paint Rock River watershed, and failed to collect live oyster mussels, but noted that conditions appeared favorable for a reintroduction of the species. In 2012, the Alabama Aquatic Biodiversity Center (AABC) initiated a reintroduction effort with 1,007 juvenile oyster mussels propagated by Virginia Tech from Clinch River broodstock. Quantitative monitoring completed at the release site in 2013, indicated 100 percent survivorship for this initial release (Johnson 2017, pers. comm.). These individuals continue to grow and survive in the river, and future releases are planned.

Duck River Dartersnapper:

Bear Creek

The AABC plans to propagate Duck River Dartersnapper for release into Bear Creek within the next few years. They are coordinating with TWRA to obtain broodstock and are continuing to perfect propagation techniques. Several attempts have been made, but insufficient adult mussel broodstock numbers were collected from the source population in the Duck River.

3) **One distinct naturally reproduced year class exists within each of the viable populations. The year class must have been produced within 5 years prior to the time the species are reclassified from endangered to threatened. Within 1 year before the delisting date, gravid females of the mussels and their host fish must be present in each viable population.**

This criterion has not been met. There are presently only two natural populations of the oyster mussel (Clinch and Nolichucky rivers), and one population of the Duck River Dartersnapper (Duck River). The Clinch and Duck rivers meet this criterion, resulting in one viable population of each species. The remaining natural extant population (Nolichucky River) is small and is threatened by heavy agriculture in the lower third of the river. The newly reestablished upper Clinch River, VA population has shown recruitment (Carey et al. 2015).

4) **Research studies of the mussels' biological and ecological requirements have been completed and any required recovery measures developed and implemented from these studies are beginning to be successful (see Recovery Tasks 1.4.1, 1.4.2, 1.4.5, and 1.4.6), as evidenced by an increase in population density of approximately 20 percent and/or increase in the length of the river reach of approximately 10 percent inhabited by the species as determined through biennial monitoring (see Recovery Task 5).**

Recovery task 1.4.1 involves conducting life history research on the oyster mussel.

Jones and Neves (2011) observed a maximum age and length of male oyster mussels (12 year and 54.6 mm) and female oyster mussels (9 year and 48.6 mm) in the Clinch River, TN. Juvenile (1-year old) recruitment ranged from 4.2-56.6% and was high when spring and summer discharge in the river was low (Jones and Neves 2011). Between 1979 and 2004, mean annual population growth rate was 12.5% and it increased to 31.4% from 2004-2008 (Jones and Neves 2011). Tang et al. (2014) estimated the growth of oyster mussel using Bayesian interpretation of mark-recapture data and provided information that may inform future Population Viability Analyses.

Jones et al. (2012) conducted reintroduction modeling, which indicated that the initial population size for a 5-year reintroduction effort greatly

affected the final population size after a 25-year period. Thus, the target population size should be reached at the end of the 5-year build-up period for the reintroduction. Genetic and demographic data suggested that the ratio of effective to census population size was about 5 percent, which would equate to a target size of 10,000 individuals (assuming an effective size of 500 individuals) for reintroduced populations (Jones et al. 2012). The age class distribution for a stable to increasing population should have multiple size classes and be comprised of small demes throughout each river targeted for restoration efforts (Jones et al. 2012).

Carey et al. (2013) determined the optimum rearing temperature for multiple mussel species, including oyster mussel, in small water-recirculating aquaculture systems. The oyster mussel achieved maximum growth at 26°C.

Recovery task 1.4.2 involves characterizing the species' habitat for all life history stages.
No additional work has occurred on this task since the last 5-year review was completed.

Recovery task 1.4.5 deals with investigating the need for management, including habitat improvement.
See downlisting Criteria #1 on page 5.

Recovery task 1.4.6 involves determining the number of individuals and the sex ratio required to maintain long-term viable natural populations.
Lane and Jones (2014) implemented mark and recapture methods for juveniles released into the Nolichucky, Clinch, and Powell rivers to estimate survival, growth, fecundity, and sex ratio for oyster mussel. Recapture and growth rates were highest in the Clinch River, and lowest in the Powell River. The ratio of males to females was nearly 1:1 in the Clinch River, but due to low growth and recapture rates, the number of individuals sexed in the other two rivers was low (Lane and Jones 2014). The average fecundity of 20 specimens was 10,854 (SE = 1,593) (Lane and Jones 2014). (Also see Recovery Task 1.4.1.)

5) **No foreseeable threats exist that would likely impact the survival of any of the species over a significant portions of their ranges (see Recovery Tasks 1.4.3 and 1.4.4).**

Recovery task 1.4.3 involves addressing present and foreseeable threats.
Agriculture, mining, and other threats continue to threaten the Duck, Nolichucky, Clinch, and Powell river watersheds (see the recovery criteria section (b) above).

Recovery task 1.4.4 deals with determining contaminant sensitivity for each life history stage. In the early 2000s, researchers began looking into

the sensitivity of multiple life history stages of mussels to contaminants (e.g., trace metals, copper, mercury, and ammonia). A summary of the relevant literature can be found in 78 FR 59281.

6) **Within larger streams (e.g., Clinch River, Duck River, Powell River), the species is distributed over a long enough reach that a single catastrophic event is not likely to eliminate or significantly reduce the entire population in that stream to a status of nonviable (see Recovery Task 4.1).**

Recovery task 4.1 involves refining techniques and methodologies for propagating and translocating mussels as a prelude to potential augmentation and reintroduction efforts.
The States of Alabama, Kentucky, Tennessee, and Virginia and Virginia Tech are working on refining mussel propagation techniques and methodologies for the oyster mussel. The Cumberlandian Region Mollusk Restoration Committee (2009) has developed a comprehensive plan for controlled propagation, augmentation and reintroduction of freshwater mollusks in the Tennessee and Cumberland watersheds.

Carey et al. (2015) evaluated oyster mussel reintroductions at three sites in the Clinch River, VA, using four reintroduction techniques: translocation of adults, release of laboratory-produced sub-adult stock, release of 8-week old laboratory-produced juveniles, and release of artificially infested fish hosts. Their results indicated that translocations of adults and release of laboratory-propagated sub-adults (> 20 mm) were the most effective reintroduction techniques for the oyster mussel.

7) **Biennial monitoring of the five species yields the results outlined in "criterion 1 and 2" over a 10-year period (see Recovery Task 5).**

Biennial monitoring has not occurred to date, primarily due to insufficient funds. Some yearly monitoring does occur by our partners on a site-by-site basis.

Oyster Mussel:
Monitoring has occurred on the Clinch and Powell Rivers at 5-year intervals since the late 1970s (Ahlstedt et al. 2016). Additionally, three sites in the Clinch River, TN have been monitored annually from 2004-2014 (Jones et al. 2014, Jones et al. unpublished data).

Duck River Dartersnapper:
Since 2010, the TWRA has monitored mussel (including the Duck River Dartersnapper) populations at three sites (Lillard's Mill, Venable Spring, and Hooper Island) on the Duck River every 5 years. The TWRA plans to continue this monitoring effort at a 5-year interval.

b. Criteria for delisting

(1) Through the protection of extant stream populations (e.g., continuing to use existing regulatory mechanisms, establishing partnerships with various stakeholders, using BMPs, minimizing or eliminating threats), discovery of currently unknown stream populations, and/or reestablishment of historical stream populations, there exists: at least **nine** (six for downlisting) distinct viable stream populations of the oyster mussel in the Cumberland River system, upper Tennessee River system, and/or lower Tennessee River system.

(2) **Two** distinct naturally reproduced year classes exist within each of the viable populations. Both year classes must have been produced within 10 years, and one-year class must have been produced within 5 years of the recovery date. Within 1 year before the recovery date, gravid females of the mussels and their host fish must be present in each viable population.

(3) All other downlisting criteria remain the same for the delisting criteria.

All the work to-date for this species has been described above under the "Criteria for downlisting." This information shows that the delisting criteria have not been met. There is presently only one viable population of the oyster mussel (Clinch River) and one for the Duck River Dartersnapper (Duck River).

C. Updated Information and Current Species Status

1. Biology and Habitat

a. **Abundance/population trends:**

Oyster Mussel:
In 2016, Phipps et al. (2017) estimated oyster mussel densities at Kyles Ford (a source site for translocations) and translocation sites in the Upper Tennessee River Basin. At Kyles Ford, TN densities of the oyster mussel increased slightly from 2.35 individuals/m^2 in 2004 to 2.58 in 2016. At Virginia sites on the Clinch River, oyster mussel density ranged from 0.04 to 0.13 individuals/m^2 in 2016 (Phipps et al. 2017).

The Clinch River densities from Phipps et al. (2017) agree with findings from Jones et al. (2014), that overall mussel densities (and densities of oyster mussel) are much lower in the Virginia portion of the Clinch River than the Tennessee portion. From 2004 to 2009, the oyster mussel showed an upward trend in the Tennessee portion of the Clinch River and was represented by multiple year classes (Jones et al. 2014). Jones et al. (2014) estimated that total population abundance

for most species showed a 50% decline in the Clinch River due to the "dead zone" present in the upper Clinch River, VA.

In 2016, oyster mussel density at the TWRA augmentation site on the Nolichucky River was 0.23 individuals/m^2 (Phipps et al. 2017). In addition to the augmentation site, there is a natural Nolichucky population approximately 20 river miles downstream from the TWRA augmentation site. The natural populations was thought to be declining before the augmentation began; however, new information indicates that the natural population has recruited within the past 10 years (Lane 2017, pers. comm.) with evidence of a large recruitment class in either 2008 or 2009 based on external shell growth. The natural population is expanding upstream (approximately 5 river miles) and now covers approximately 4-5 miles of the lower end of the river. There are several year classes present at four documented locations. Genetic analyses have shown that the natural Nolichucky River population contains lower genetic diversity than the Clinch River population (Lane and Jones 2017, unpubl. data).

Phipps et al. (2017) also evaluated oyster mussel translocations to the Hiwassee and Emory rivers in 2016. They found very few native mussels at the TWRA mussel restoration sites on these rivers and concluded the translocations were unsuccessful. In 2017, TWRA discontinued translocation efforts at these sites on the Hiwassee and Emory rivers.

Duck River Dartersnapper:
In 2010 and 2015, the TWRA monitored mussel (including the Duck River Dartersnapper) populations at three (Lillard's Mill, Venable Spring, and Hooper Island) sites on the Duck River. Duck River Dartersnapper density decreased from 2010 to 2015 at two of the three sites (Lillard's Mill and Venable Spring) (Hubbs 2016). At Lillard's Mill, Duck River Dartersnapper density decreased from 4.70 m^2 in 2010 (population estimate 15,745; 95% CI, 14,874 – 16,616) to 0.75 m^2 in 2015 (population estimate of 1,530, 95% CI, -348 – 3,408), but remained above the density measured in 1988 (0.40 m^2) (Hubbs 2016). At Venable Spring, Duck River Dartersnapper abundance was estimated to be 2,250 in 2015 (95% CI, 764 – 3,735) down 72% from 7,950 (95% CI, 7,017 – 8,883) in 2010. Its density decreased from 2.65 m^2 in 2010 to 0.75 in 2015. The Hopper Island Duck River Dartersnapper population was the only site that showed improvement. After not being collected during quantitative sampling at this site in 1988 or 2002; density increased 80% from 0.25 m^2 in 2010 to 0.45 in 2015 (Hubbs 2016). The estimated abundance increased from 685 (95% CI, -1,655 – 3,025) to 1,260 individuals (95% CI, -437 – 2957). The declines in density were attributed to large floods on the river

between the two sampling periods (2010, 2011, and 2013 floods) (Hubbs 2016).

The Duck River Dartersnapper represented approximately two percent of all mussels collected during qualitative surveys of the Duck River between 2000 and 2002, and a range expansion was noted (Ahlstedt et al. 2004). Although methods were not comparable to those in 2010 and 2015, Johnson (2017, pers. comm.) notes that there appears to be a decline in the population and that attempts to obtain broodstock have been unsuccessful over the past two years.

In summary, oyster mussel and Duck River Dartersnapper densities appear to fluctuate between years. However, in comparisons to known trends when the last five-year review was conducted, in 2009, oyster mussel densities have decreased across the range of the species. One notable exception to the declines, has been the observations of reintroduced individuals in the Nolichucky River.

b. **Genetics:** In 2010, Jones and Neves described a new morphologically and genetically diagnosable species in the oyster mussel complex. The new species, *E. ahlstedti* is described from the Duck River, and likely occurred historically in the Buffalo River and the Tennessee River at Muscle Shoals and Shoal Creek, Lauderdale County, AL. Populations upstream from Muscle Shoals in the Tennessee River system remain the oyster mussel, *E. capsaeformis* (Clinch River system, Tennessee River drainage). For a complete list of morphological and genetic diagnostic features for the new species, see Jones and Neves (2010).

   Jones et al. (2015) compares mitochondrial and nuclear DNA estimates of effective population size and evaluate dispersal techniques for the oyster mussel.

c. **Taxonomic classification or changes in nomenclature:** The oyster mussel was recognized as *Epioblasma capsaeformis* [Lea, 1834] at the time the Recovery Plan was written in 2004.

   In 2010, Jones and Neves described a new morphologically and genetically diagnosable species in the oyster mussel complex. The new species, *E. ahlstedti* is described from the Duck River, and likely occurred historically in the Buffalo River and the Tennessee River at Muscle Shoals and Shoal Creek, Lauderdale County, AL. Populations upstream from Muscle Shoals in the Tennessee River system remain the oyster mussel, *E. capsaeformis* (Clinch River system, Tennessee River drainage). For a complete list of

morphological and genetic diagnostic features for the new species, see Jones and Neves (2010).

The newly described taxa (Jones and Neves 2010) will also be recognized in the next edition of the "Common and scientific names of mussels from the United States, Canada, and Mexico. . ." (Butler 2016, pers. comm.). Based on the best available information, the Service believes the original listing of oyster mussel should be revaluated under the Act in consideration of the accepted work of Jones and Neves (see section IV. Future Recommendations).

d. Spatial distribution:

Oyster Mussel:
Based on the recent taxonomic changes, the historical range of the oyster mussel is now limited to the upper Tennessee River system and the Cumberland River system. The proposed taxonomic changes would make the *E. capsaeformis* restricted to the upper Tennessee and Cumberland watersheds. The lower Tennessee watershed represents the new species, Duck River Dartersnapper.

Duck River Dartersnapper:
The historical range of the Duck River Dartersnapper includes the Duck and Buffalo Rivers in the lower Tennessee River system.

e. **Habitat or ecosystem conditions:** While oil and gas development and coal mining were listed as threats to the oyster mussel in both the Recovery Plan and the last 5-year review, new research is beginning to shed light on the specific chemical constituents primarily responsible for declines in freshwater mussels, such as the oyster mussel. In sites impacted by coal mining or natural gas extraction, total recoverable metals, polycyclic aromatic hydrocarbons (PAHs), major ions, or a combination of the three likely have contributed to sediment toxicity and mussel declines in the Upper Tennessee and Cumberland River basins (Wang et al. 2013, Cope and Jones 2016). Oil and gas wastewater from both conventional and unconventional wells have been shown to be a risk to aquatic organisms due to halide and ammonium levels in waters, even after brine treatment (Harkness et al., 2015).

Price (2011) indicates total dissolved solids concentrations have continued to rise in the Powell and Clinch Rivers, with rapid increases in the upper Powell River, where coal mining is most prominent. Price et al. (2014) and Zipper et al. (2016) found a

temporal increase of dissolved solids in the Clinch and Powell Rivers between 1964 and 2010 that corresponds to declining mussel densities in the Virginia portions of each river. In addition, water-column ammonia and sediment metals have occurred at levels likely to contributing to the decline of freshwater mussels in the Virginia portions of the each river (Price et al. 2014). The increased levels of ammonia, metals, and dissolved solids were seen in watersheds drained by both agricultural activity and coal mining; however, mussel declines are greater in close proximity to and downstream of watersheds impacted by coal mining (upper Powell River and Guest River, a tributary to the Clinch River) (Price et al. 2014).

Johnson et al. (2014) found higher turbidity and specific conductance in Clinch River reaches with low quality mussel assemblages when compared to reaches with high quality mussel assemblages. Additionally, higher major ions and water column metals concentrations were also seen in the low quality mussel assemblage reaches (Johnson et al. 2014, Zipper et al. 2016). The low quality mussel assemblages were spatially associated with tributary inflow from basins draining Pennsylvanian shale and coal geologic formations, and were diluted by tributary basins with no mining (Johnson et al. 2014).

Land cover analyses of the Clinch River watershed between Clinchport and Artrip, VA, (Cope and Jones 2016) indicate that developed land cover and impervious surfaces increased by approximately 40 percent between 2001 and 2011. This area is described as a "Zone of Decline" (ZOD) for freshwater mussels and stressors include wastewater and stormwater discharges, industrial and commercial discharges, oil and gas operations, and surface coal mining operations (Jones et al. 2014, Cope and Jones 2016).

A combination of factors appears to be impacting this ZOD in the Clinch River; however, PAHs were consistently prevalent at sites within the ZOD and there were consistent concentrations when comparing mussel tissues and samples of sediment and surface water (Cope and Jones 2016). The PAH sources within the study reach are thought to be mining-associated tributaries: the Guest River and Dumps Creek (Cope and Jones 2016). Furthermore, their observations show that the PAH (and most metals tested) levels in tissues are due to recent rather than long-term exposure (Cope and Jones 2016). The PAHs might have a chronic lethal effect on mussels, while metals have a sub-lethal effect on the growth of mussels; however, conductivity, turbidity and other

environmental stressors likely interact in unpredictable ways to impact mussel health and survival (Cope and Jones 2016). Cope and Jones (2016) also observed that ammonia and manganese were detrimental to mussel survival and biomass, particularly in sediments from the Guest River and Copper Creek. The source appears to be mining in the Guest River watershed, while agriculture is the predominant land use in the Copper Creek watershed. The source of the high levels of manganese in Copper Creek are unknown at this time (Cope and Jones 2016).

Echols et. al. (2012) assessed the toxicity of brine discharge to test organisms, including freshwater mussels but not the oyster mussel specifically. However, oyster mussel glochidia were used for 48-hour reference toxicant sodium chloride tests, and were more sensitive than most mussel species.

In October 2016, a mussel die-off was observed at Kyles Ford and Frost Ford in the Clinch River, TN (Chance and Hubbs, pers. obs. 2016). Causes of the die-off and mussel population impacts are still being investigated at the time of writing this review (September 2017).

2. Five Factor Analysis (threats, conservation measures and regulatory mechanisms).

Factor A. The present or threatened destruction, modification, or curtailment of its habitat or range:

As indicated in the Recovery Plan (USFWS 2004), impoundments, channelization, mineral extraction, gravel mining, contaminants, toxic chemical spills, and sedimentation remain threats to the oyster mussel. Additional, ongoing threats to the mussel include increased urbanization, streambank erosion, water withdrawals, and agricultural practices.

Non-point source pollution from land surface runoff can originate from virtually any land use activity (such as coal mining and agricultural activities) and may be correlated with impervious surfaces and storm water runoff from urban areas. Pollutants entering the Nolichucky, Clinch, Powell, and Duck rivers may include sediments, fertilizers, herbicides, pesticides, animal wastes, pharmaceuticals, septic tank and gray water leakage, and petroleum products. These pollutants tend to increase concentrations of nutrients and toxins in the water and alter the chemistry of affected streams such that the habitat and food sources for species like the oyster mussel are negatively impacted.

Coal mining activity has decreased in the Clinch and Powell River watersheds in recent years; however, mining in the Powell River watershed still impacts water quality in the watershed (Zipper et al. 2016). In particular, specific conductance, pH, dissolved solids, alkalinity, hardness, and sulfate are temporally correlated with progression of mining in the Powell River watershed (Zipper et al. 2016).

Factor B. Overutilization for commercial, recreational, scientific or educational purpose: The overutilization for commercial, recreational, scientific or educational purposes was not considered to be a limiting factor in the Recovery Plan. We have no new information to indicate that this has changed.

Factor C. Disease and predation: The Recovery Plan stated that there is little data indicating that disease or predation are limiting factors for this species. We have no other information on disease or predation of the oyster mussel. We continue to believe that disease and/or predation are not limiting factors for this species.

Factor D. Inadequacy of existing regulatory mechanisms: The oyster mussel and its habitats are afforded limited protection from water quality degradation under the Clean Water Act of 1977 (33 U.S.C. 1251 et seq.) and the Tennessee Water Quality Control Act of 1977. These laws focus on point-source discharges, and many water quality problems are the result of non-point source discharges. Therefore, these laws and corresponding regulations have been inadequate to halt population declines and degradation of habitat for the oyster mussel.

In addition to the federal listing, the oyster mussel is listed as Endangered by the State of Tennessee. Under the Tennessee Nongame and Endangered or Threatened Wildlife Species Conservation Act of 1974 (Tennessee Code Annotated §§ 70-8-101-112), "…it is unlawful for any person to take, attempt to take, possess, transport, export, process, sell or offer for sale or ship nongame wildlife, or for any common or contract carrier knowingly to transport or receive for shipment nongame wildlife." Further, regulations included in the Tennessee Wildlife Resources Commission Proclamation 00-15 Endangered Or Threatened Species state the following: except as provided for in Tennessee Code Annotated, Section 70-8-106 (d) and (e), it shall be unlawful for any person to take, harass, or destroy wildlife listed as threatened or

endangered or otherwise to violate terms of Section 70-8-105 (c) or to destroy knowingly the habitat of such species without due consideration of alternatives for the welfare of the species listed in (1) of this proclamation, or (2) the United States list of Endangered fauna. Potential collectors of this species would be required to have a state collection permit.

Since listing, section 7 of the Act has required Federal agencies to consult with the Service when projects they fund, authorize, or carry out may affect the species. However, the lack of Federal authority over the many actions likely impacting oyster mussel habitat has become apparent. Many of the threats (including those identified at the time of listing, during recovery planning, and since development of the Recovery Plan) involve activities that likely do not have a Federal nexus (such as water quality changes resulting from development, water withdrawals, or indiscriminate logging) and, thus, may not result in section 7 consultation. Although the take prohibitions of section 9 of the Act do apply to these types of activities and their effects on the oyster mussel, enforcement of the section 9 prohibitions is difficult, at best. The Service is not informed when many activities are being considered, planned, or implemented; therefore, we have no opportunity to provide input into the design of the project or to inform project proponents of the need for a section 10 permit. Unlike higher profile species, conservation of the oyster mussel is not valued by most of the public to the extent that citizens would report to the Service the likelihood of habitat destruction or illegal taking. A non-regulatory approach to providing for conservation of the oyster mussel may be most effective in alleviating threats.

Factor E. Other natural and manmade factors affecting its continued existence: The Recovery Plan listed the presence or potential introduction of non-native species (especially zebra mussels and black carp), insufficient densities of host fish species, inbreeding depression and other genetic considerations, and possible weak links in the species' life cycles.

New species of Asian carp (*Hypophthalmichthys* spp.) have spread into the Duck River. It in unknown how these exotic carp will influence the Duck River Dartersnapper, however, there is some concern that because both Asian Carp and mussels are filter-feeders there is potential food web disruption and impacts to freshwater mussels.

D. Synthesis

The oyster mussel was historically one of the most widely distributed Cumberlandian mussel species. Its range historically included four physiographic provinces (Interior Low Plateau, Cumberland Plateau, Ridge and Valley, and Blue Ridge) and six States (Alabama, Georgia, Kentucky, North Carolina, Tennessee, and Virginia). In the Cumberland River, it occurred from the base of Cumberland Falls, McCreary and Whitley counties, KY, downstream to Stewart County, TN. In the Tennessee River, it occurred throughout the main stem, downstream to Colbert and Lauderdale Counties, AL. Dozens of tributaries in the Cumberland and Tennessee River systems also harbored this species historically. The oyster mussel is now considered extirpated from the entire Cumberland River system, although augmentations in the Big South Fork Cumberland River should be assessed. Oyster mussels also have been eliminated from the entire Tennessee River main stem and numerous tributaries. The remaining natural extant populations occur in the Clinch and Nolichucky rivers.

The Duck River population has been determined to be a separate species, the Duck River Dartersnapper, and has only one extant population and should be considered for listing under the Act.

The Recovery Plan listed excessive sedimentation (primarily resulting from nonpoint-source loading), coal mining, gravel mining, reduced water quality below existing dams, developmental activities, water withdrawal, impoundments, and alien species as threats to the oyster mussel and its habitat. Due to the restricted range of the remaining two extant populations of oyster mussel and one population of Duck River Dartersnapper, toxic spills are also a threat that could wipe out an entire population. All of these threats remain.

The recovery criteria listed in Section B above have not been met for delisting or downlisting the oyster mussel. Because of the oyster mussel's limited distribution and continued threats to the two extant populations, it remains in danger of extinction throughout all or a significant portion of its range. Therefore, the status of the oyster mussel should remain as endangered. The Duck River Dartersnapper, and has only one extant population and we recommend this mussel to be considered for listing under the Act. Until that time, we believe the originally listed entity continues to meet the definition of endangered.

At the time of listing (USFWS 1997), the oyster mussel had a high degree of threat and a low recovery potential, which results in a Recovery Priority Number of 5 for the taxonomic level of species. The Recovery Plan (USFWS 2004) also describes this species as having a high degree of threat and a low recovery potential. We continue to believe that the threats to this species

remain high and that the recovery potential remains low. Therefore, a change to the existing Recovery Priority Number is not necessary.

III. RESULTS

A. Recommended Classification: No change is needed for the existing classification of endangered for the oyster mussel. We recommend that the Duck River Dartersnapper should be considered for listing under the Act.

IV. RECOMMENDATIONS FOR FUTURE ACTIONS

Oyster Mussel:

- Continue efforts to augment and expand the range of extant populations to ensure their viability. For example, the following Cumberlandian Region streams were recommended by the Cumberlandian Region Mollusk Restoration Committee (CRMRC) (2010): Tennessee River system – upper Clinch, VA; upper Powell, TN/VA; Nolichucky, TN. Cumberland River system – Big South Fork, TN/KY.
- Reestablish viable populations in other streams within the historical range that have suitable habitat and water quality. For example, the following Cumberlandian Region streams were recommended by the CRMRC (2010): Tennessee River system – Tennessee main stem tailwaters: Wilson, AL, Pickwick Landing, TN, Bear Creek, AL; Tennessee tributary tailwaters: lower French Broad/Holston, TN, Elk, AL; Paint Rock, AL; Copper Creek, VA; Emory, TN; upper Powell River, VA; upper North Fork Holston, VA; upper French Broad, TN; lower Pigeon, TN; Hiwassee, TN; Estill Fork of the Paint Rock River, AL; upper Holston, TN; Little Pigeon, TN; Bear Creek, AL/MS; Buffalo, TN; Shoal Creek, TN/AL. Cumberland River system – Rockcastle, KY; Buck Creek, KY; Little South Fork, KY. Smith et al (2017) rank the Nolichucky, Upper Clinch, and Powell rivers as the highest priority Tennessee River sub-basins for reintroduction efforts.
- Monitor native Nolichucky River population and reassess the need for augmentation activities in the upper portion of the river.
- Protect habitat through acquisitions and easements.
- Develop guidance to assist state regulatory authorities and local USFWS field offices in developing protective measures for Biological Opinions.
- Continue to educate the public about water quality and freshwater mussels.
- Continue quantitative and qualitative efforts to monitor existing populations, including long-term monitoring efforts. Demographic

and genetic monitoring should be used to monitor populations over time.

Duck River Dartersnapper:

- We recommend that the Duck River Dartersnapper, described by Jones and Neves (2010), be considered for listing status.
- Determine the life history characteristics of the Duck River Dartersnapper.
- Determine the appropriate source population for Elk River reintroductions. The oyster mussel and Duck River Dartersnapper could have both occurred sympatrically in the Elk River historically.
- Develop propagation technology and reintroduce the species into its historical range in the lower Tennessee River drainage. For example, the following Cumberlandian Region streams were recommended by the Cumberlandian Region Mollusk Restoration Committee (CRMRC) (2010): Tennessee River system – Limestone Creek, AL; Bear Creek, AL; Buffalo River, TN; Shoal Creek, TN/AL; and the mainstem Tennessee River below Wilson and Pickwick Landing Dams. In Alabama, Bear Creek would be the top priority, followed by Shoal Creek. Limestone Creek would not be appropriate for the Duck River Dartersnapper and has widespread habitat problems (Johnson 2017, pers. comm.).
- Protect habitat through acquisitions and easements.
- Continue quantitative and qualitative efforts to monitor existing populations, including long-term monitoring efforts. Demographic and genetic monitoring should be used to monitor populations over time.
- Continue to educate the public about water quality and freshwater mussels.

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U.S. FISH AND WILDLIFE SERVICE
5-YEAR REVIEW of **Oyster Mussel (*Epioblasma capsaeformis*)**

Current Classification: Endangered
Recommendation resulting from the 5-Year Review:

__X__ No change is needed

Review Conducted By: Stephanie Chance, Cookeville, TN Ecological Services Field Office

FIELD OFFICE APPROVAL:

Lead Field Supervisor, Fish and Wildlife Service

Approve _____ Date 3/12/19

REGIONAL OFFICE APPROVAL:

Pof **Cooperating Regional Director, Fish and Wildlife Service, Northeast Region**

__X__ Concur ____ Do Not Concur

Signature _____ Date 2/28/19

APPENDIX A: Summary of peer review for the 5-year review of the oyster mussel (*Epioblasma capsaeformis*)

A. Peer Review Method: Emails were sent to Steve Ahlstedt (USGS retired), Braven Beaty (TNC), Pandy English (TWRA), Steve Fraley (NCWRC), Jeff Garner (ALDCNR), Don Hubbs (TWRA), Paul Johnson (ALDCNR), Bill Kittrell (VADGIF), Tim Lane (VADGIF), Monte McGregor (KYDFWR), Amanda Rosenberger (TTU), Brian Watson (VADGIF), and Jason Wisniewski (GADNR) requesting that they peer review the scientific portions of the oyster mussel 5-year review document. Peer reviewers were given 30 days to complete the review.

B. Peer Review Charge: An email was sent to each peer reviewer along with the biological portion of the 5-year review and a list of the literature cited. We explained to the peer reviewers that in order to support the Service's interest in making its decision based on the best available science, portions of the draft review need to be subjected to an appropriate level of peer review. They were told that due to their expertise regarding this species, we are requesting that they peer review the enclosed portion of the document.

C. Summary of Peer Review Comments/Report: We received comments from six peer reviewers. The majority of the comments related to updating the recovery criteria of reestablishing populations and the abundance and population trends portions of the document. The peer reviewers and Jess Jones (FWS - Region 5) support the recommendation for the newly described taxon to be considered for listing.

D. Response to Peer Review: All the peer review comments were incorporated into the 5-year review document.